AGN at ~1-100 MeV

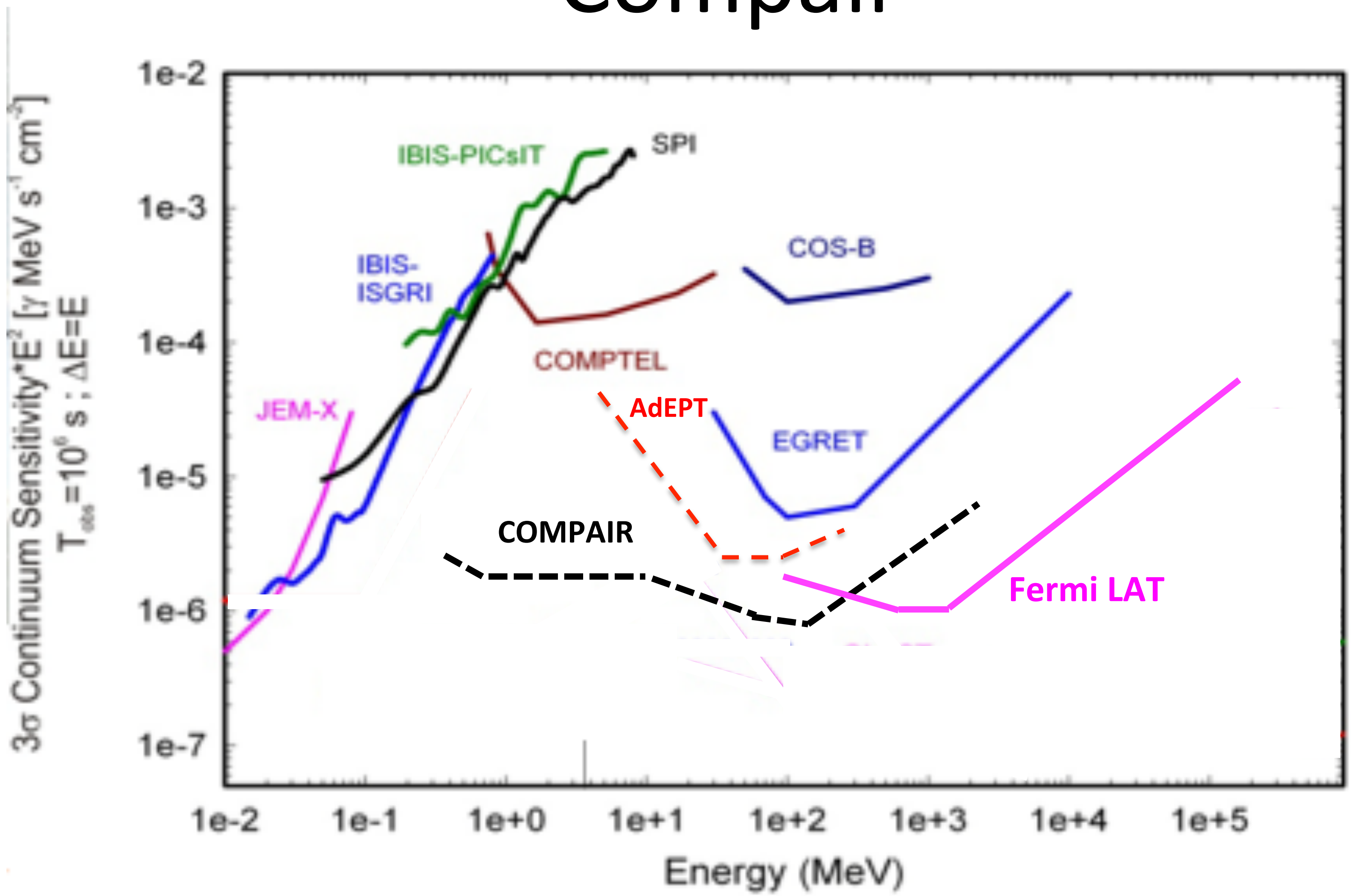
(Especially non-blazar AGN)

(Also a little bit about polarization from blazars)

Justin Finke (NRL)

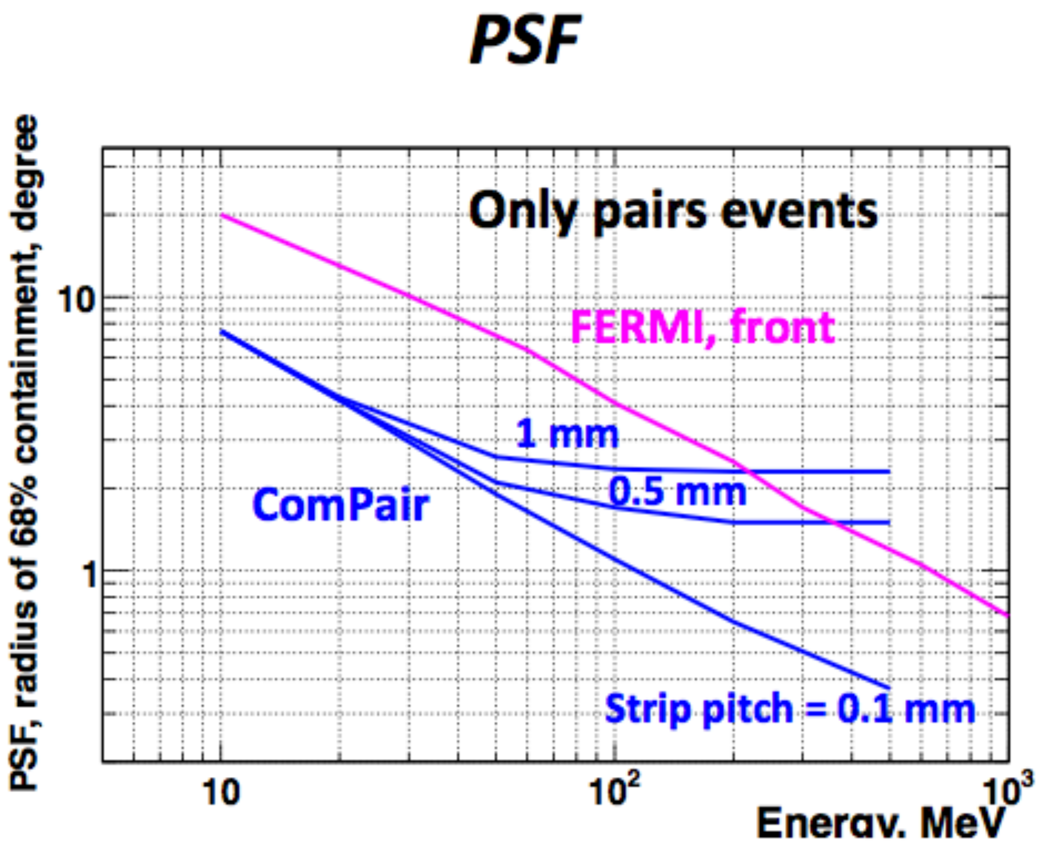
GSFC 24 March 2016

Compair



3σ Continuum Sensitivity*E² [γ MeV s⁻¹ cm⁻²]
T_obs=10⁶ s ; ΔE=E
1e-2
1e-3
1e-4
1e-5
1e-6
1e-7
1e-2
1e-1
1e+0
1e+1
1e+2
1e+3
1e+4
1e+5
Energy (MeV)
IBIS-PICsIT
SPI
COS-B
IBIS-
ISGRI
COMPTEL
JEM-X
AdEPT
EGRET
COMPAIR
Fermi LAT

Compair

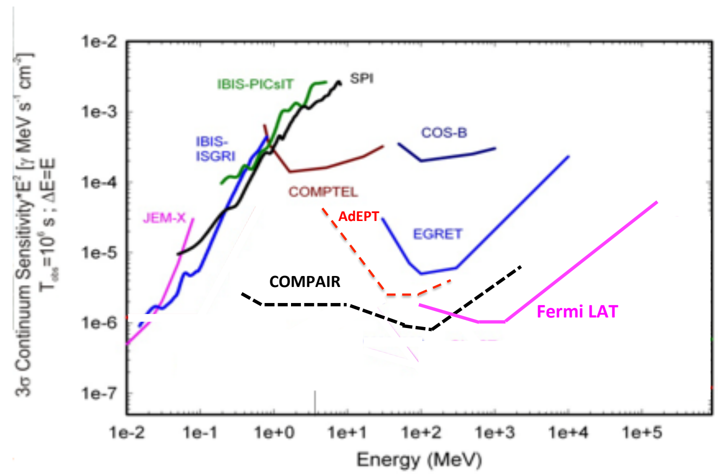


PSF:
7° at 10 MeV
1° at 100 MeV

1-100 MeV Telescope

- Assume 10^{-12} erg cm^{-2} s^{-1} in ~1 Msec (11.5 days) and flux sensitivity goes as sqrt(time)
- It will reach 10^{-13} erg cm^{-2} s^{-1} in ~3 years.
- Will it be wide field of view instrument like Fermi? Multiply timescales by 5

Compare with COMPTEL which reached ~ 10^{-10} erg cm^{-2} s^{-1}



Alex Moiseev Future Space-based Gamma-ray observations Feb 6, 2015 GSFC

Radio Quiet AGN

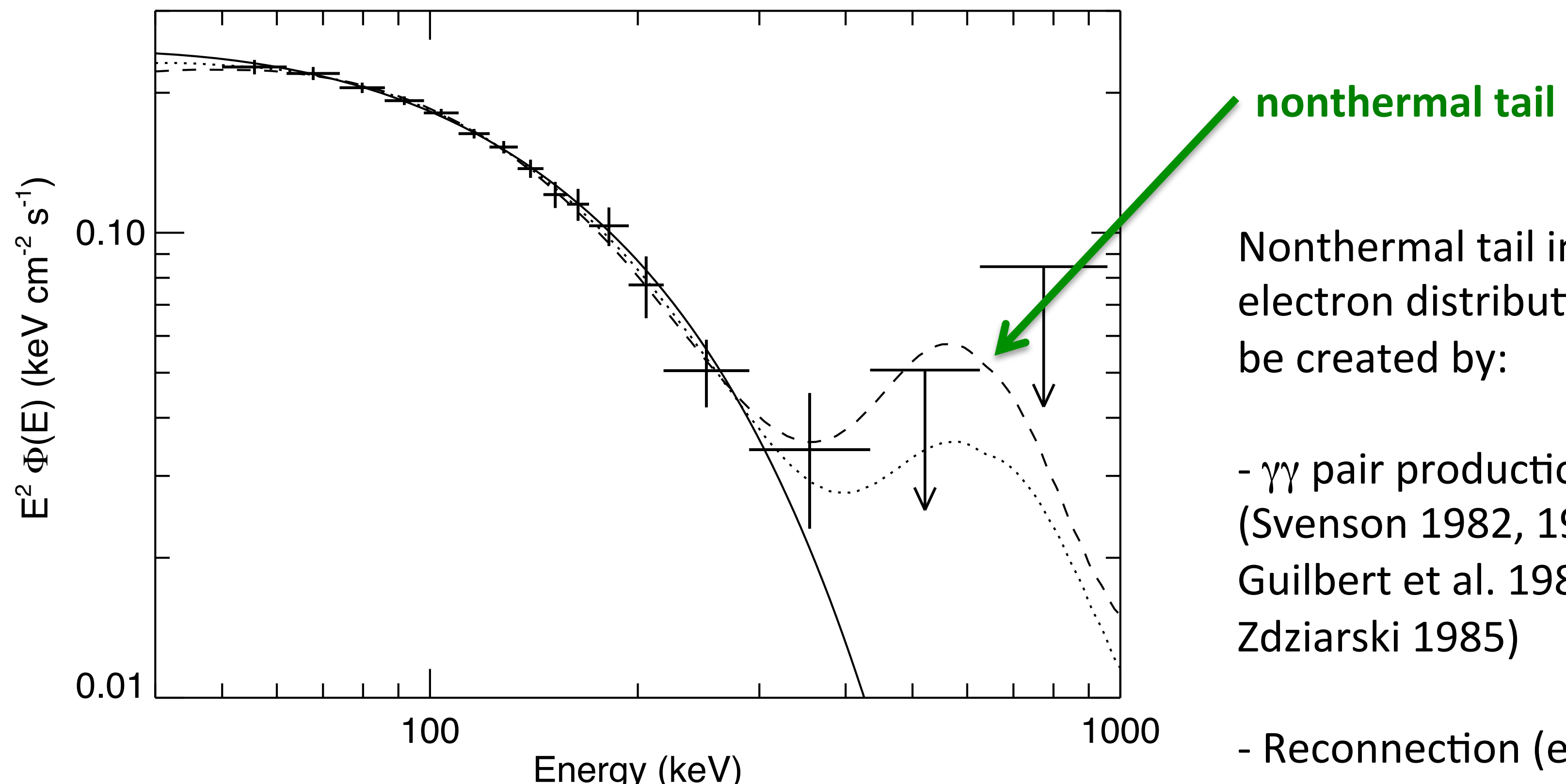
Hot thermal corona
"hot", geometrically thick, optically thin (?)
produces > 1 keV X-rays

Czerny & Janiuk (2007), A&A, 464, 167

Thermal disk
"cold", geometrically thin, optically thick
produces <1 keV X-rays

Hot corona creates X-rays by inverse Compton-scattering colder thermal disk emission.

Radio Quiet AGN



OSSE spectrum of NGC 4151
Johnson et al. (1997), ApJ, 482, 173

Nonthermal tail in electron distribution can be created by:

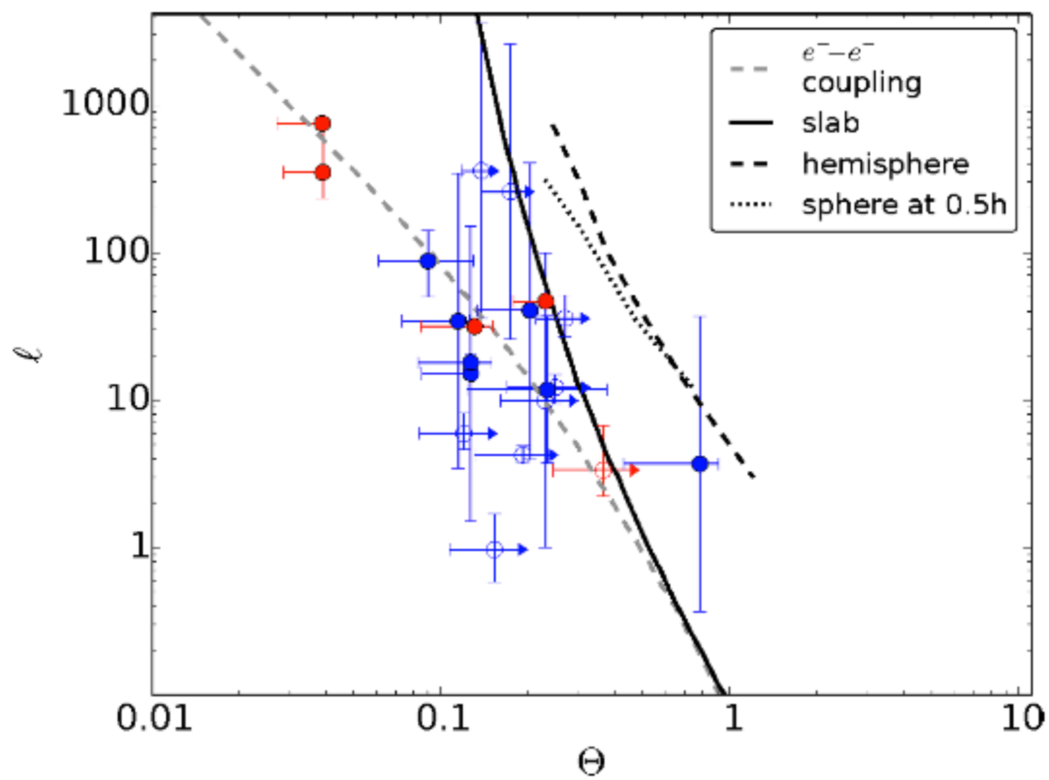
- $\gamma\gamma$ pair production (Svenson 1982, 1984; Guilbert et al. 1983; Zdziarski 1985)

- Reconnection (e.g. Liu et al. 2002, ApJ, 572, L173)

Radio Quiet AGN

Nonthermal tail can be created by γγ pair production in hot corona.

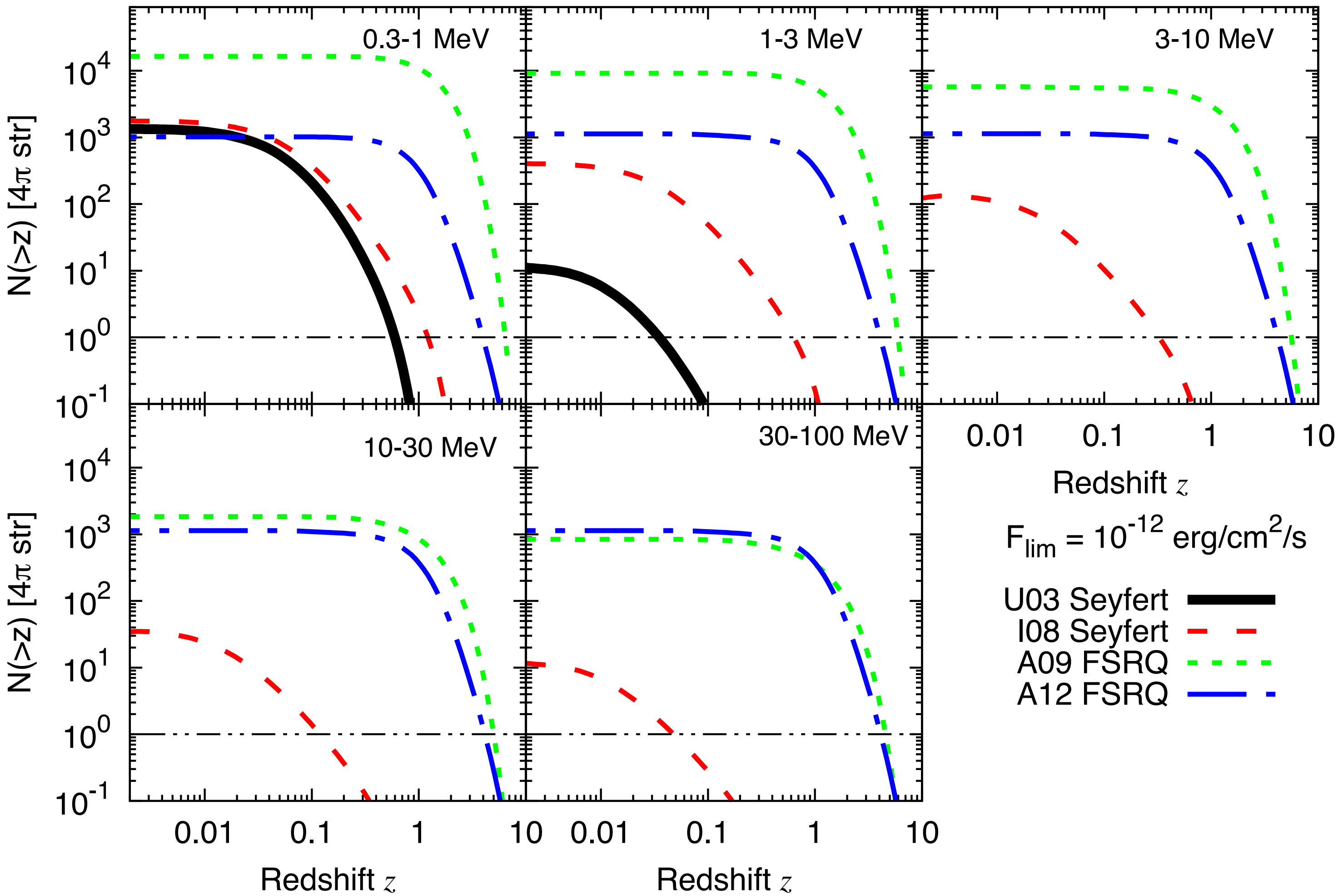
It has been proposed that pairs can regulate temperature in corona (Fabian et al. 2015). Potentially testable with MeV observations of nonthermal tail.



NuSTAR

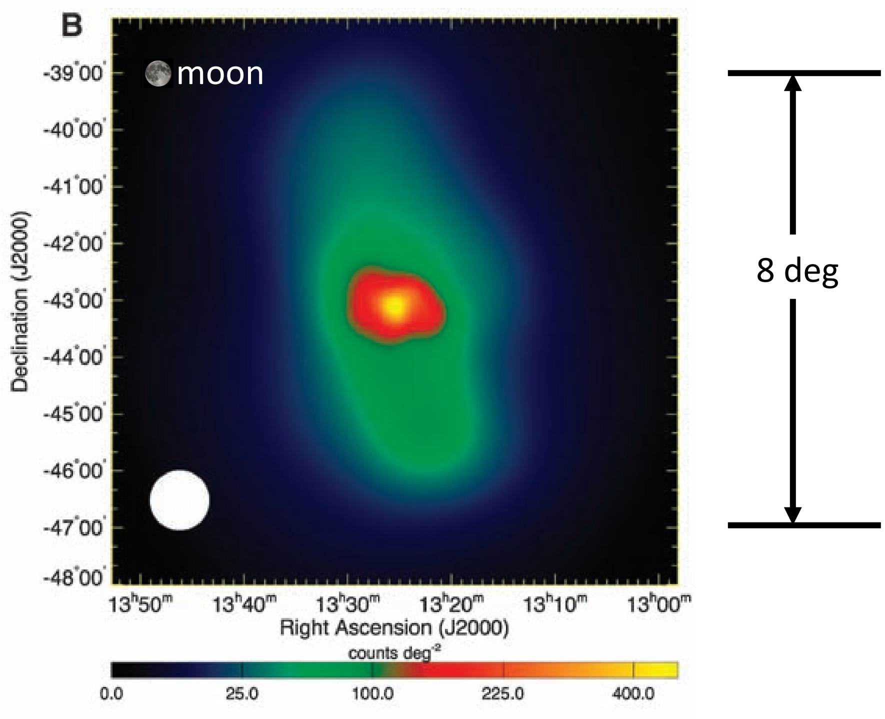
Fabian et al. (2015), MNRAS, 451, 4375

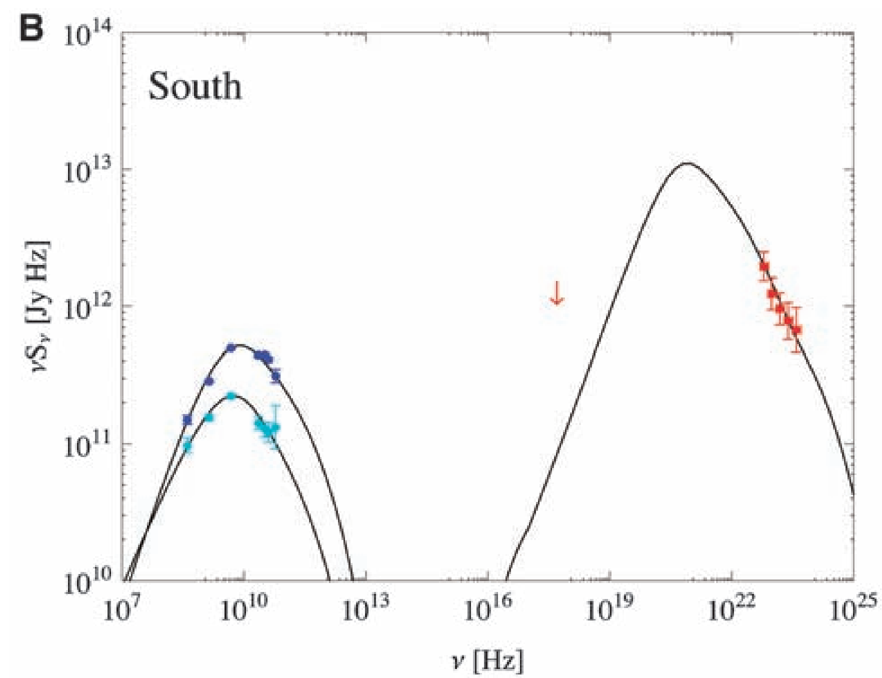
AGN population



Inoue et al. (2015), PASJ, 67, 76

Cen A Lobes





Could Compair resolve the Cen A lobes?

PSF:

7° at 10 MeV

1° at 100 MeV

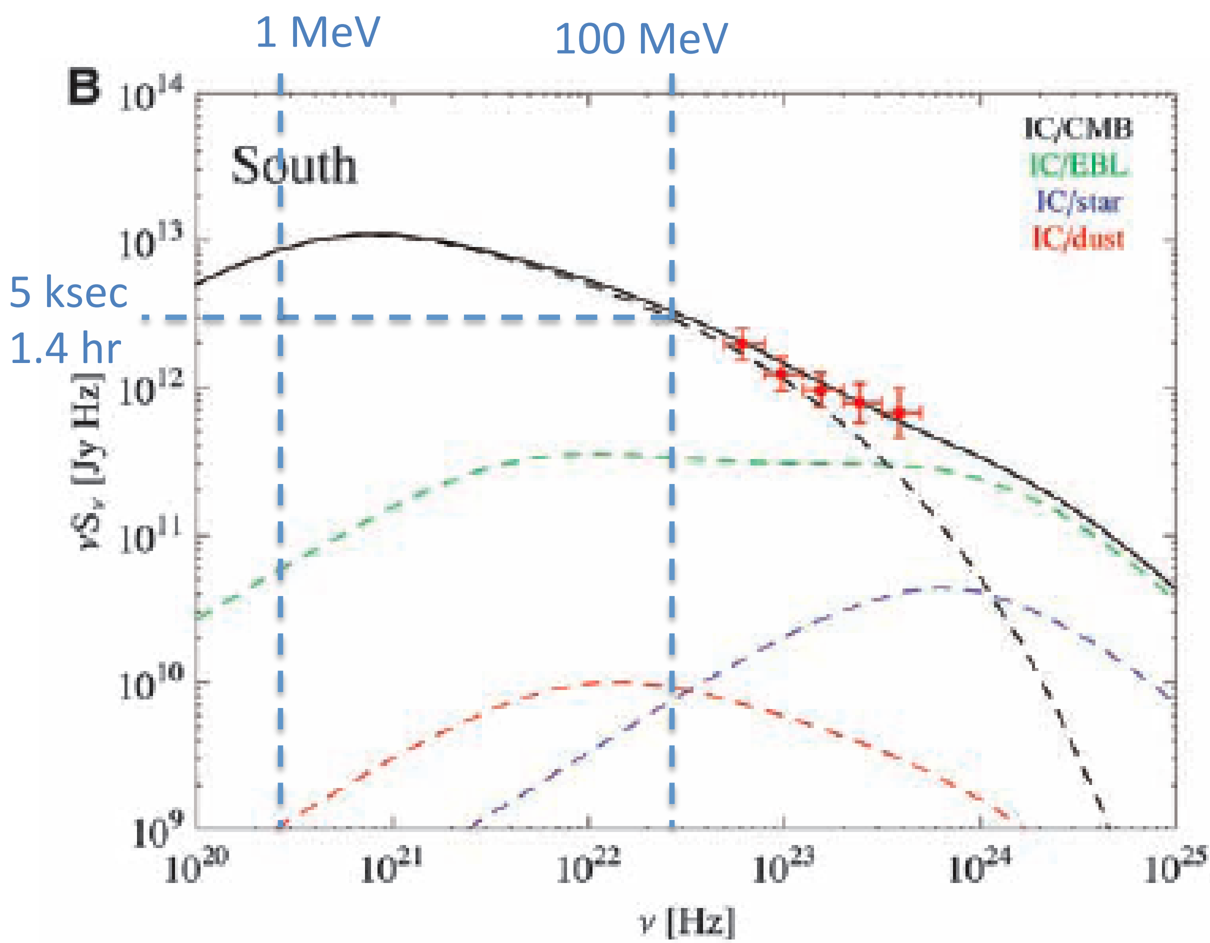
Abdo et al. (2010), Science, 328, 725

Cen A Lobes

Could be used to constrain the EBL!

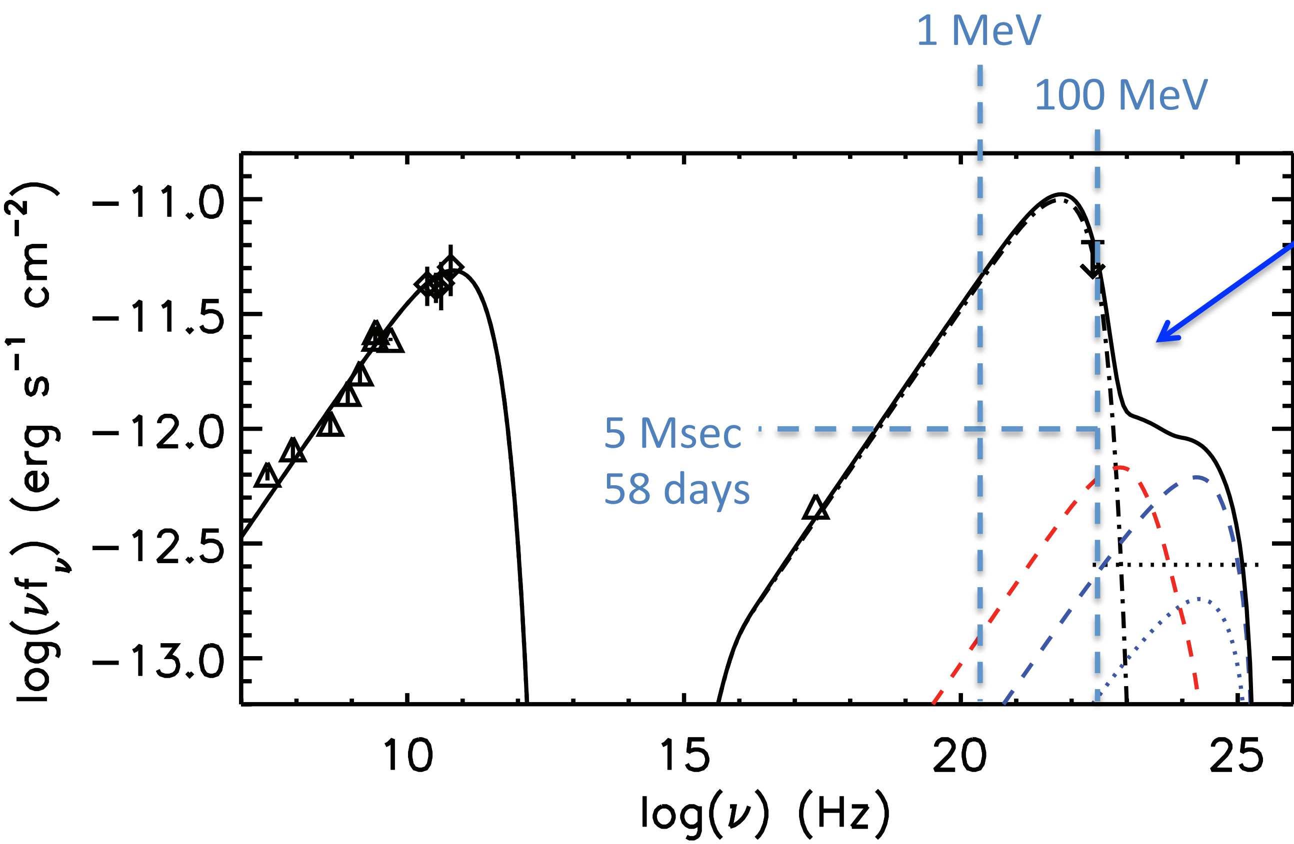
Georganopoulos et al. (2008), ApJ, 686, L5

Previous γ-ray constraints on EBL rely on opacity, but there are ways around it (UHECRs, axions, etc.). Compton scattering constraints would avoid that problem.



Abdo et al. (2010), Science, 328, 725

Radio galaxy lobes



Cutoff: LAT has problem seeing radio lobes!

Fornax A

Georganopoulos et al. (2008), ApJL, 686, L5

Radio galaxy lobes

TABLE 2

Spectral Fits for X-Ray Lobe Detections with Sufficient Counts

Source		Net Counts[a]	N_H[b] (cm^{-2})	Γ[c]	$S_{1\ keV}$[c] (nJy)	χ^2/dof	**Extrapolated 1-100 MeV Flux [erg cm^{-2} s^{-1}]**
3C 47N	z=0.425	197	5.87×10^{20}	1.4 ± 0.4	3.6 ± 0.7	4.9/6	10^{-11}
3C 47S		434	5.87×10^{20}	1.9 ± 0.2	10 ± 1	21/15	3×10^{-13}
3C 215N	z=0.411	109	3.75×10^{20}	1.4 ± 0.3	2.9 ± 0.4	1/3	10^{-11}
3C 215S		119	3.75×10^{20}	1.5 ± 0.5	2.9 ± 0.5	2.9/3	4×10^{-12}
3C 219N	z=0.174	188	1.51×10^{20}	2.0 ± 0.3	9 ± 1	3.6/6	10^{-13}
3C 219S		147	1.51×10^{20}	1.7 ± 0.5	7 ± 1	7/4	10^{-12}
3C 265E	z=0.811	142	1.90×10^{20}	1.9 ± 0.2	3.1 ± 0.3	1/5	9×10^{-14}
3C 452 (model I)[d]	z=0.081	2746	1.19×10^{21}	1.75 ± 0.09	37 ± 2	96/89	4×10^{-12}
3C 452 (model II)[d]		2746	1.19×10^{21}	1.5 (frozen)	23 ± 4	87/88	3×10^{-11}

Red: detectable in < 5 Msec (58 days)

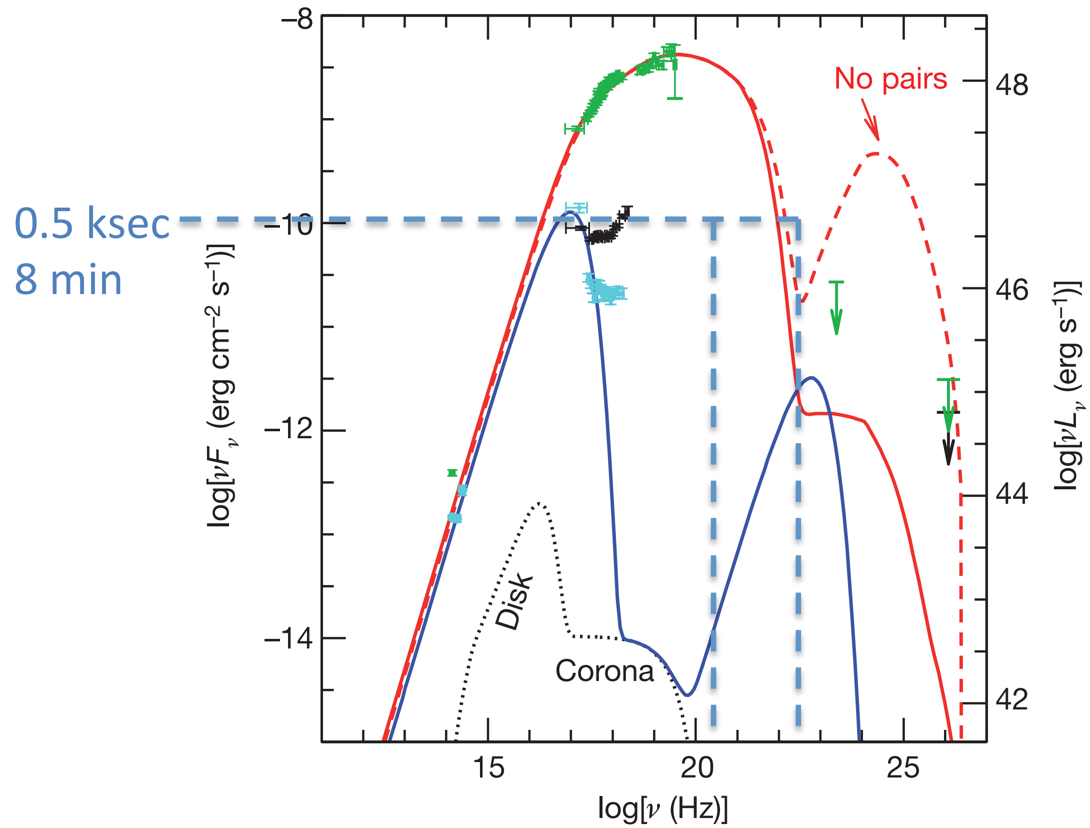
Croston et al. (2005), ApJ, 626, 733

Tidal Disruption Events

Energetics: constrained by stellar mass

Magnetic field needed to generate a jet (e.g. Kelley et al. 2014)?

Compair would easily have easily have seen Swift J164449.3+1573451 .



Burrows et al. (2011), Nature, 476, 421

Polarization

ADEPT: polarization at 5-200 MeV

Will be able to detect 10% polarization for 10 mCrab (3×10^{-11} erg cm^{-2} s^{-1}) in 10^6 sec

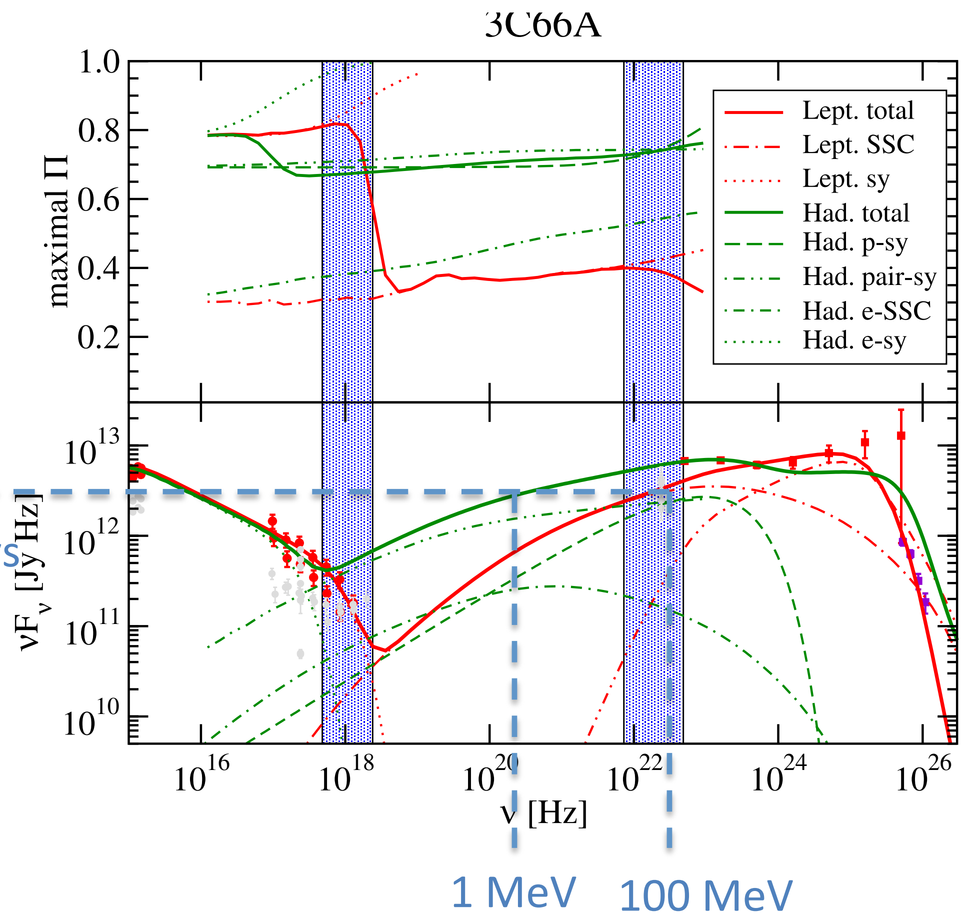
Angular resolution ~0.6 deg at 70 MeV

(Hunter et al. 2014, Astroparticle Physics, 59, 18)

Polarization

leptonic models: γ rays from inverse Compton
hadronic models: γ rays from synchrotron (p and pγ decay products)

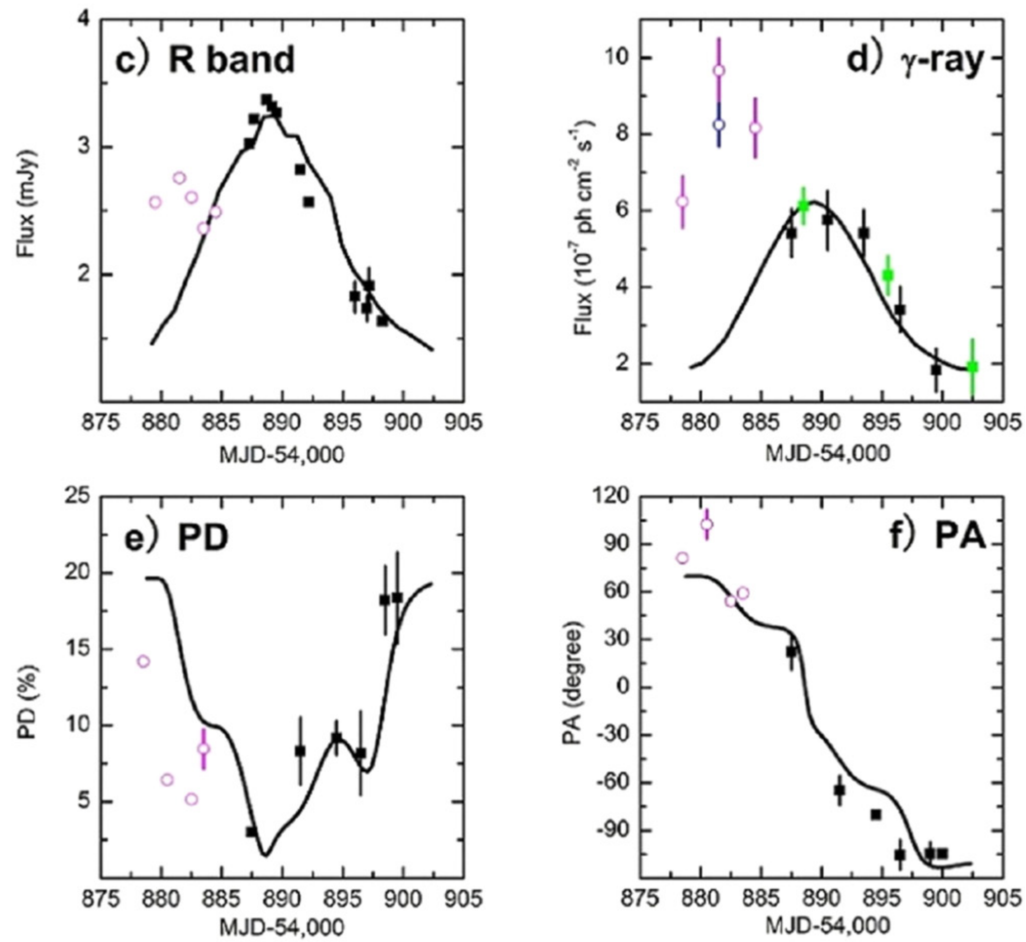
MeV energy polarization could distinguish leptonic and hadronic models (Zhang & Boettcher 2013).



Zhang & Boettcher (2013), ApJ, 774, 18

Polarization

MeV polarization on day timescales could probe jet magnetic field structures (Zhang & Boettcher 2014; Zhang et al. 2015) but this seems unlikely to be possible.



3C 279; Zhang et al. (2015), ApJ, 804, 58

Conclusions

- An Compair type MeV instrument will see:
  - At least 1000 blazars
  - Up to 100 radio quiet AGN
  - Some radio galaxy lobes (probably more than Fermi)
  - Possibly tidal disruption events, if they occur

- Polarization with ADEPT (for example): distinguish leptonic/hadronic models for γ-ray emission from blazars

Extras

- Thanks to:
  - Roopesh Ojha
  - Greg Madejeski
  - Abe Falcone
  - Teddy Cheung
- Opinions and mistakes are mine alone

COMPTEL

3EG: 94 AGN (Hartman et al. 1999)

3FGL: 1679 AGN (Acero et al. 2015)

COMPTEL saw 15 radio loud AGN and 0 radio quiet AGN (Collmar 2006)

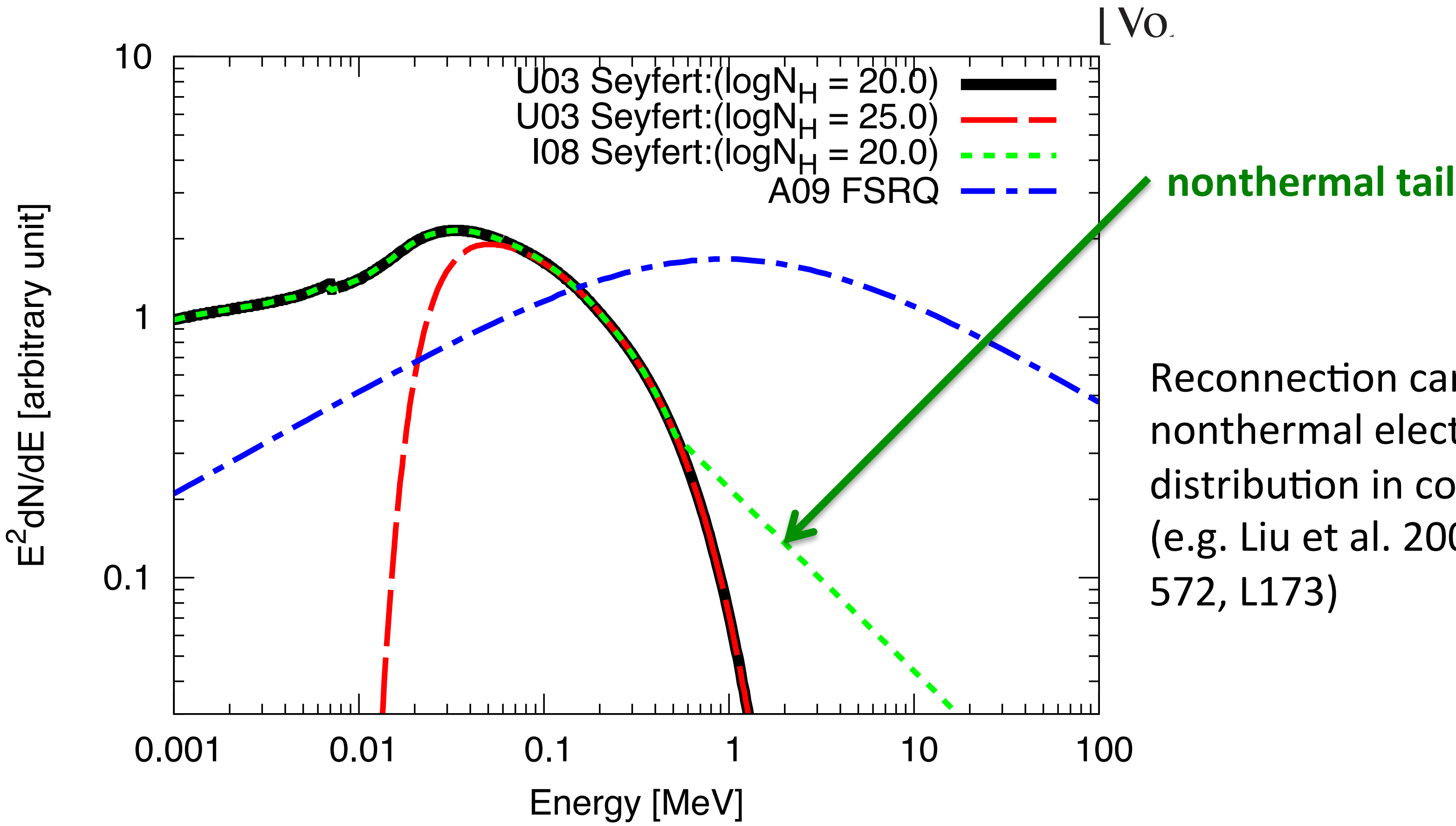
How many AGN will a future MeV telescope see?

Table 1. Updated list of COMPTEL AGN detections. Apart from the four new sources and Mkn 421 (Collmar et al. 1999), all others are listed in the first COMPTEL source catalog. The table lists the source name, the redshift, the AGN type, and a qualitative statement on the COMPTEL detection significance.

Source	Redshift	AGN Type	Significance
Cen A	0.0007	radio galaxy	high
Mkn 421	0.031	BL Lac object	low
3C 273	0.158	quasar	high
PKS 1222+216	0.435	quasar	medium
3C 279	0.538	quasar	high
PKS 1622-297	0.815	quasar	high
3C 454.3	0.859	quasar	high
PKS 0208-512	1.003	quasar	high
CTA 102	1.037	quasar	low
GRO J0516-609	1.09	quasar	medium
PKS 1127-145	1.187	quasar	medium
PKS 0528+134	2.06	quasar	high
PKS 0716+714	?	BL Lac object	low
0836+710	2.17	quasar	medium
PKS 1830-210	2.06	quasar	medium

Collmar (2006)

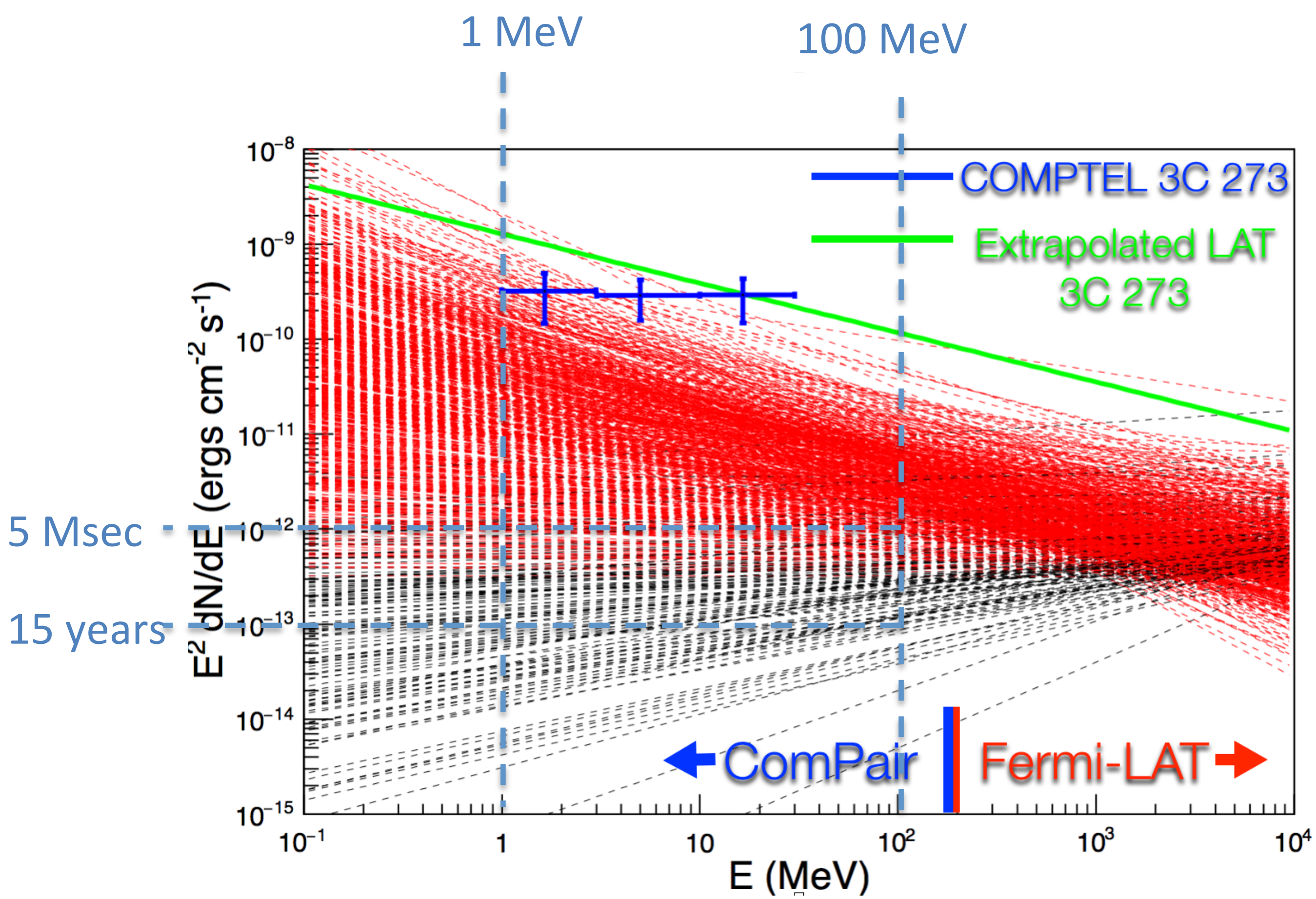
Radio Quiet AGN



Reconnection can create nonthermal electron distribution in corona (e.g. Liu et al. 2002, ApJ, 572, L173)

Inoue et al. (2015), PASJ, 67, 76

Compair

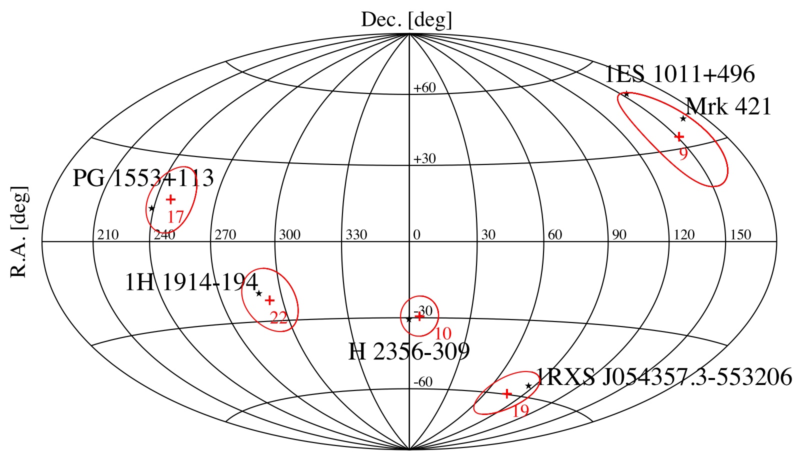


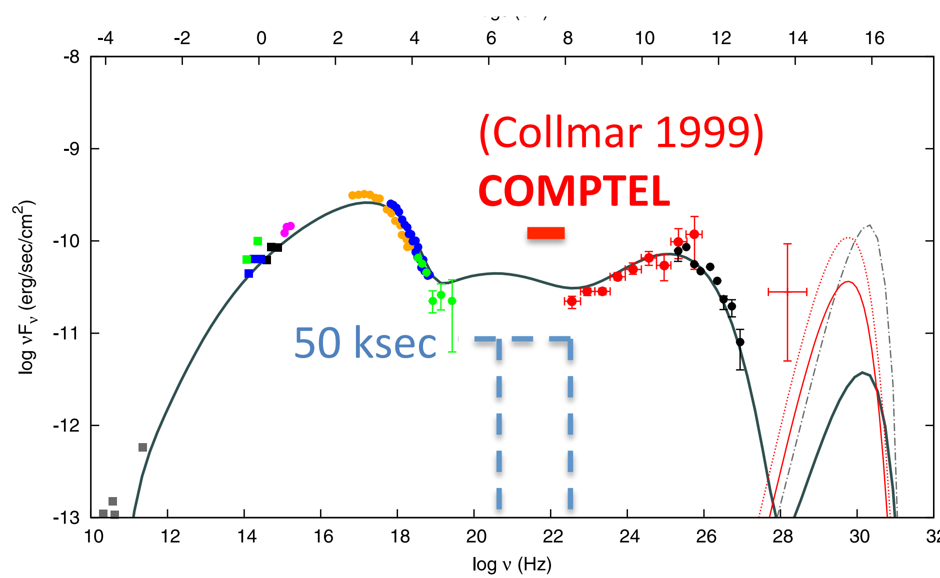
1 MeV
100 MeV
COMPTEL 3C 273
Extrapolated LAT 3C 273
5 Msec
15 years
E^2 dN/dE (ergs cm^{-2} s^{-1})
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-1}
1
10
10^2
10^3
10^4
E (MeV)
ComPair
Fermi-LAT

Hadronic models for γ-ray emission

Hadronic models for FSRQs have mostly been ruled out for FSRQs based on energetics (Sikora et al. 2009; Zdziarski & Boettcher 2015).

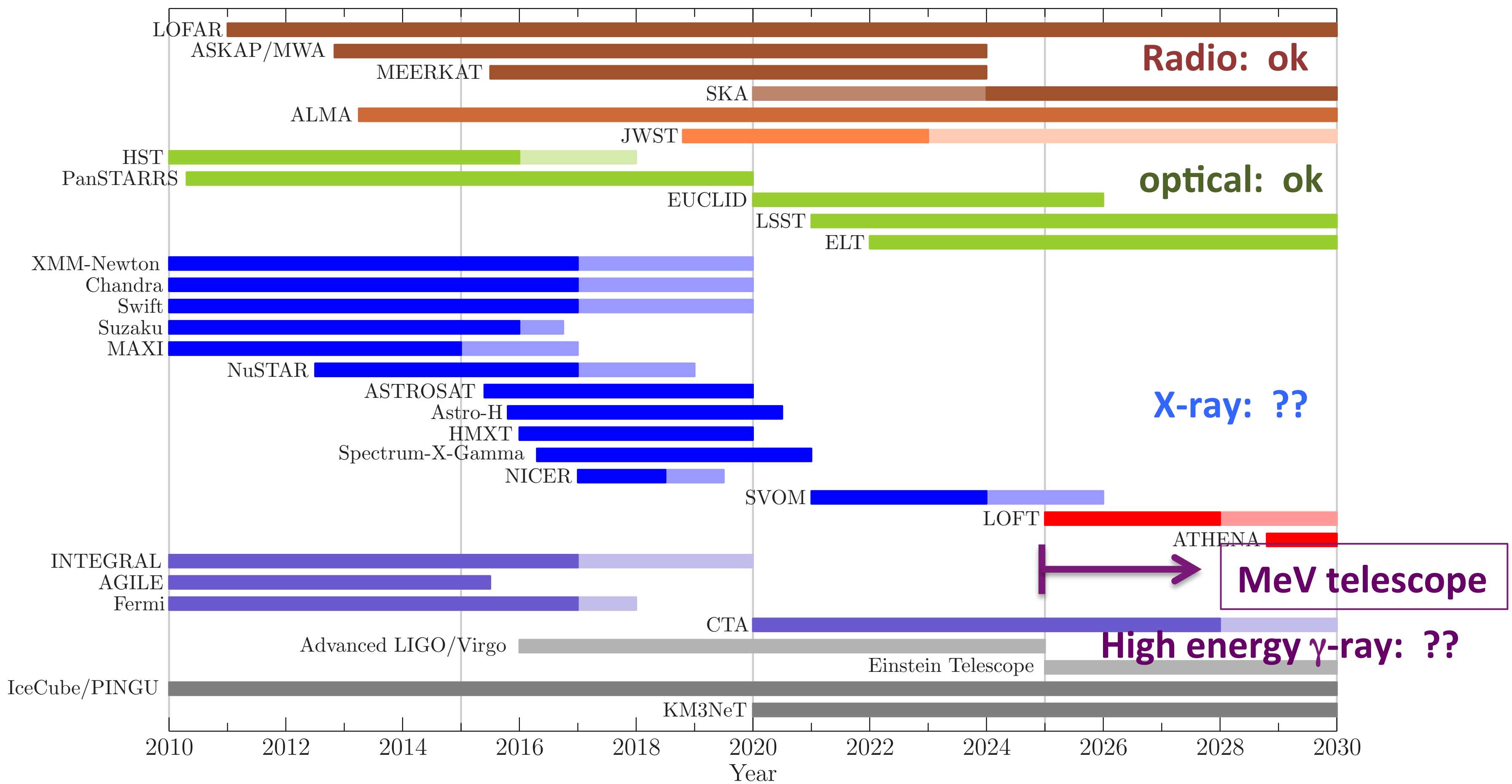
What about HSP BL Lacs?



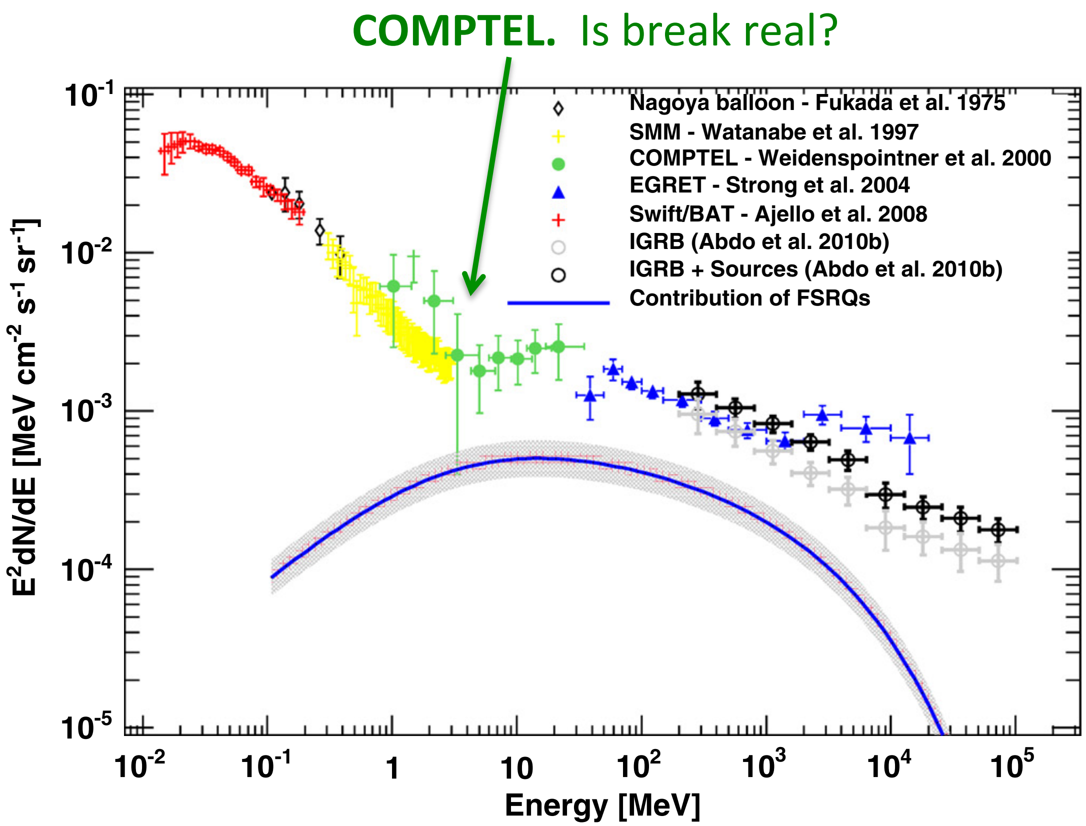


Petropoulou et al. (2015), MNRAS, 448, 2412

Multi-Wavelength



MeV background



Ajello et al. (2012), ApJ, 751, 108

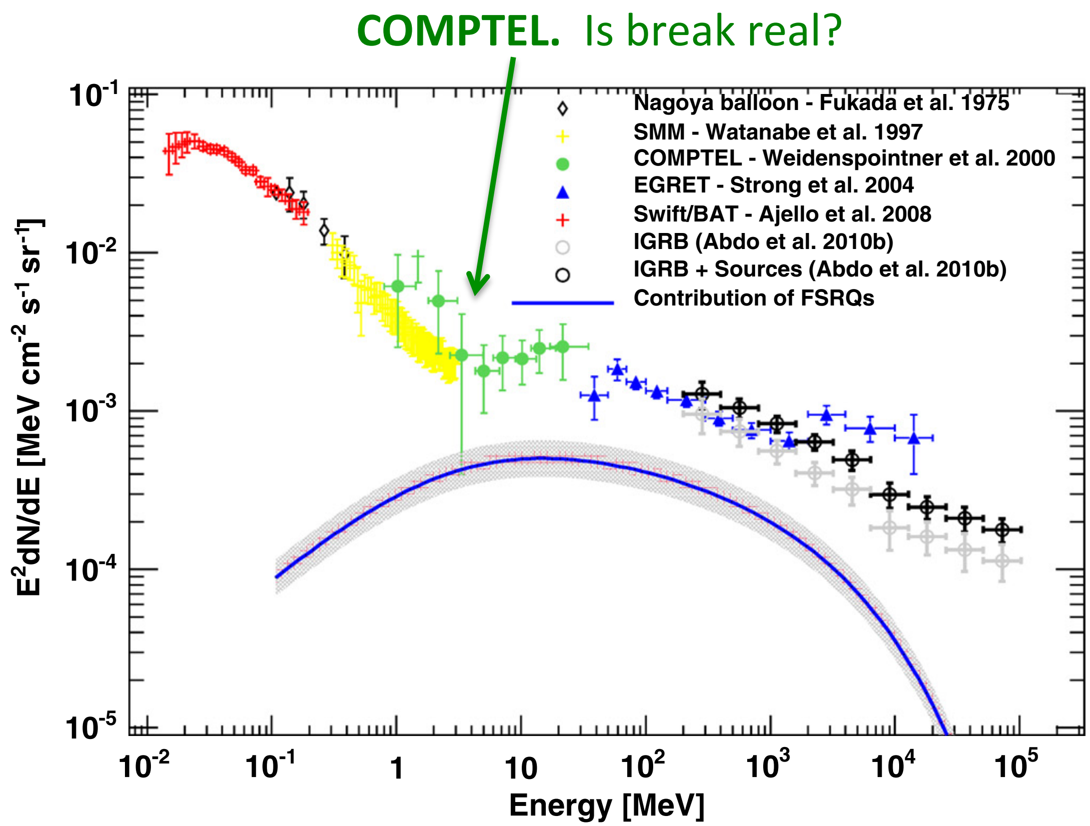
Type Ia supernovae?
About 10% (e.g., Strigari et al., 2005; Horiuchi & Beacom, 2010; Ruiz-Lapuente et al., 2015)

Radio galaxies?
About 10% (Massaro & Ajello 2011, Inoue 2011)

Star-forming galaxies?
<~ 10% (Lacki et al. 2014)

Dark matter?

MeV background



Ajello et al. (2012), ApJ, 751, 108

Extrapolating from BAT: FSRQs make up entire MeV background.

Extrapolating from LAT: FSRQs make up 30% of MeV background.

Only a small fraction of the MeV background will be resolved.

Inoue et al. (2015), PASJ, 67, 76